The Thompson Dimensional Scaling Framework: A Universal Extension of Physical Laws Across Higher-Dimensional Spacetimes

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Abstract

Most physical laws were developed in a fixed 4-dimensional spacetime, making them inadequate for theories that involve extra dimensions, such as string theory or brane cosmology. The Thompson Dimensional Scaling Framework (TDSF) introduces a universal scaling factor, $\left(\frac{D-2}{2}\right)^{\lambda}$, to generalize classical, quantum, and relativistic laws to arbitrary spacetime dimensions without altering their 4D behavior. This reformulation unifies diverse physical domains under a single scaling principle and enables new predictions in quantum gravity, vacuum energy, and cosmology. Crucially, TDSF yields testable consequences—such as modified Casimir forces and dimensional redshifts—that offer a pathway from theoretical speculation to empirical validation.

1 Introduction

Most of the physical laws that form the foundation of modern science were formulated within a four-dimensional spacetime framework—three spatial dimensions and one temporal dimension. Whether in Newtonian mechanics, Maxwell's equations, or Einstein's field equations, the assumption of a fixed 4D background is built into nearly every equation. However, advances in high-energy physics, string theory, and cosmological modeling have long suggested the existence of additional dimensions—dimensions that, if real, would necessitate a reformulation of how we understand mass, energy, force, and even the vacuum itself.

Despite this, few attempts have been made to reexpress these foundational laws in a way that allows for systematic variation in the number of dimensions. Most theories that incorporate extra dimensions treat them as passive geometrical features—compactified or hidden—but do not reformulate the laws of physics themselves as functions of dimensionality.

The Thompson Dimensional Scaling Framework (TDSF) addresses this gap by introducing a consistent scaling factor of the form:

$$\left(\frac{D-2}{2}\right)^{\lambda}$$

where D is the number of spacetime dimensions and λ is a scaling exponent specific to each physical context. This factor generalizes traditional 4D formulations without discarding them, allowing physical laws to retain their familiar forms in our observed universe while being extendable to higher-dimensional models.

The implications of this approach are substantial. By systematically applying this scaling principle to classical mechanics, quantum dynamics, field theory, and zero-point physics, we obtain a coherent structure that both unifies disparate equations and introduces new testable predictions. This paper presents the core principles of TDSF, reformulated physical laws, and a pathway toward experimental validation of higher-dimensional physics.

2 The Scaling Principle

The foundation of the Thompson Dimensional Scaling Framework lies in the recognition that most physical laws implicitly assume a four-dimensional spacetime. These laws are not, by construction, invariant under changes in dimensionality. Yet higher-dimensional models—particularly those from string theory, M-theory, and brane cosmology—require a mathematical structure that behaves consistently as D varies.

The proposed scaling factor in TDSF is:

$$\left(\frac{D-2}{2}\right)^{\lambda}$$

where:

- D is the total number of spacetime dimensions (including time),
- λ is a dimension-dependent exponent specific to the physical quantity or law being generalized.

The form $(D-2)/2$ is not arbitrary. It reflects the fact that:

1. Two of the D dimensions (typically time and one spatial axis) are functionally fixed in many dynamical systems, leaving $D-2$ as the set of dimensions influencing force propagation or energy distribution.

2. The division by 2 normalizes the factor in such a way that when $D=4$, the scaling reduces to 1:
$$\left(\frac{4-2}{2}\right)^{\lambda} = 1^{\lambda} = 1$$
ensuring that all standard 4D formulations are recovered exactly.

The exponent λ serves as a tunable parameter. While in this paper it is treated as a free parameter determined by context, future work may derive λ from underlying geometric or energetic principles (e.g., curvature scaling, brane tension, or mode density).

In what follows, we apply this scaling principle systematically across a variety of physical laws to produce their dimensional generalizations. Each reformulated law preserves its 4D behavior while gaining explicit dependence on the dimensionality of spacetime—a step toward building a cohesive, falsifiable model of higher-dimensional physics.

3 Geometric Foundations of the Scaling Factor

The use of $\left(\frac{D-2}{2}\right)^{\lambda}$ as a universal dimensional scaling factor is rooted in the geometry of higher-dimensional spacetime. The term $D-2$ arises naturally in three contexts: (1) from the surface area of a $(D-2)$-sphere, which governs the dilution of force fields via Gauss's law; (2) from the divergence of radial vector fields, which determines the power-law decay of forces; and (3) from the spectral density of quantum modes in vacuum fluctuations, where the number of contributing states scales as ω^{D-2}. The division by 2 serves to normalize the scaling so that all standard 4D physics is recovered when $D=4$, ensuring compatibility with experiment while extending to higher-dimensional models. In this way, the Thompson Dimensional Scaling Framework reflects not only mathematical convenience but also geometric necessity.

4 Dimensional Extensions of Classical Laws

The Thompson Dimensional Scaling Framework (TDSF) can be used to reformulate classical physical laws by applying the dimension-sensitive scaling factor $\left(\frac{D-2}{2}\right)^{\lambda}$. This allows each

law to remain consistent with its well-established 4D form while extending it to arbitrary spacetime dimensions.

4.1 Newton's Law of Universal Gravitation

In D dimensions, Newton's gravitational law becomes:

$$F_D = G_D \cdot \left(\frac{D-2}{2}\right)^{\lambda} \cdot \frac{m_1 m_2}{r^2}$$

where G_D is the gravitational constant in D-dimensional spacetime. This equation preserves the familiar inverse-square dependence while introducing a dimension-aware correction to the force magnitude.

4.2 Coulomb's Law

Similarly, the electrostatic force between charges generalizes as:

$$F_D = k_D \cdot \left(\frac{D-2}{2}\right)^{\lambda} \cdot \frac{q_1 q_2}{r^2}$$

where k_D is the permittivity-dependent Coulomb constant in D dimensions. This accounts for potential geometric and field-strength differences as dimensionality changes.

4.3 Hubble's Law

For cosmological expansion, the Thompson-scaled version of Hubble's Law is:

$$v = H_0 \cdot \left(\frac{D-2}{2}\right)^{\lambda} \cdot d$$

This suggests that the recessional velocity of galaxies could scale with dimensional parameters, with possible implications for interpreting redshift-distance data in the presence of extra dimensions.

4.4 Planck Energy

The Planck energy in D dimensions becomes:

$$E_{P,D} = \left(\frac{D-2}{2}\right)^{\lambda} \cdot \sqrt{\frac{\hbar c^5}{G_D}}$$

This formulation indicates how the energy scale of quantum gravity may shift depending on the dimensional structure of spacetime.

Each of these equations exemplifies the power of TDSF to preserve classical physics while opening new theoretical and experimental avenues.

5 Dimensional Extensions of Quantum Laws

Quantum mechanical laws are similarly sensitive to the structure and geometry of spacetime. Applying the Thompson Dimensional Scaling Framework (TDSF) introduces corrections that generalize these laws beyond four dimensions while retaining their core mathematical forms.

5.1 Schrödinger Equation

The time-dependent Schrödinger equation in D dimensions becomes:

$$i\hbar\frac{\partial\psi}{\partial t} = \left(\frac{D-2}{2}\right)^{\lambda}\left(-\frac{\hbar^2}{2m}\nabla^2 + V\right)\psi$$

This scaling modifies the kinetic and potential energy operators in higher-dimensional contexts while preserving standard behavior when $D = 4$.

5.2 de Broglie Wavelength

The de Broglie relation becomes:

$$\lambda_D = \left(\frac{D-2}{2}\right)^{\lambda}\cdot\frac{h}{p}$$

This suggests that wave-particle duality may exhibit measurable shifts in higher-dimensional or compactified scenarios.

5.3 Heisenberg Uncertainty Principle

The uncertainty principle in TDSF reads:

$$\Delta x\Delta p \geq \left(\frac{D-2}{2}\right)^{\lambda}\cdot\frac{\hbar}{2}$$

Here, dimensionality introduces a rescaling of quantum indeterminacy that may be probed in precision measurements.

5.4 Fine-Structure Constant

TDSF modifies the effective fine-structure constant as:

$$\alpha_D = \left(\frac{D-2}{2}\right)^{\lambda} \cdot \frac{e^2}{4\pi\varepsilon_0\hbar c}$$

This dimensional correction could affect the strength of electromagnetic interactions in brane-world or extra-dimensional contexts.

These generalizations of quantum laws under TDSF offer a framework not only for unification but also for identifying subtle experimental signals of extra dimensions.

6 Field Equations in the Thompson Framework

The Thompson Dimensional Scaling Framework (TDSF) also provides a systematic method for extending relativistic field equations to arbitrary spacetime dimensions. This includes both geometric formulations, such as general relativity, and field-theoretic constructs from gauge theory and string dynamics.

6.1 Einstein Field Equations

The Einstein field equations scale in D dimensions as:

$$\left(\frac{D-2}{2}\right)^{\lambda} G_{\mu\nu}^{(D)} = 8\pi G_D \left(\frac{D-2}{2}\right)^{\lambda} T_{\mu\nu}^{(D)}$$

This retains the fundamental relationship between spacetime curvature and energy-momentum while embedding the dimensional dependence into both geometric and source terms.

6.2 Maxwell's Equations (Gauss's Law Form)

Electromagnetic field equations generalize as:

$$\nabla \cdot \vec{E} = \left(\frac{D-2}{2}\right)^{\lambda} \cdot \frac{\rho}{\varepsilon_0}$$

This implies that electric flux and charge density scale with dimension, affecting field strength predictions in higher-dimensional electrodynamics.

6.3 Gauge Field Equations

More generally, gauge fields governed by field strength tensors obey:

$$\nabla_\mu \left(\left(\frac{D-2}{2} \right)^\lambda F^{\mu\nu} \right) = \left(\frac{D-2}{2} \right)^\lambda J^\nu$$

This preserves the gauge invariance structure while introducing a dimensional weight to interaction terms.

6.4 Polyakov String Action

For string-theoretic considerations, the Polyakov action becomes:

$$S_D = -\frac{T_0}{2} \left(\frac{D-2}{2} \right)^\lambda \int d^2\sigma \sqrt{-h} h^{ab} \partial_a X^\mu \partial_b X^\nu g_{\mu\nu}^{(D)}$$

This formulation embeds the scaling factor directly into the worldsheet action, allowing for consistent dimensional dependence in string dynamics.

Collectively, these field equations demonstrate that TDSF offers a unified correction structure that is compatible with both classical gravitation and quantum field theory, while preserving the form and symmetry principles of their original formulations.

7 Dimensional Consistency and Unit Analysis

Dimensional analysis confirms that the Thompson Dimensional Scaling Framework preserves the physical units of all reformulated equations. The scaling factor $\left(\frac{D-2}{2}\right)^\lambda$ is dimensionless by construction, ensuring that any equation multiplied by it retains its original dimensional structure.

As an illustrative example, the fine-structure constant α remains dimensionless under TDSF:

$$\alpha_D = \left(\frac{D-2}{2} \right)^\lambda \cdot \frac{e^2}{4\pi\varepsilon_0 \hbar c} \quad \Rightarrow \quad [\alpha_D] = 1 \tag{1}$$

Furthermore, Planck units remain consistent when gravitational constant G_D is treated as a dimension-dependent quantity. The Planck energy, for instance, is given by:

$$E_{P,D} = \left(\frac{D-2}{2} \right)^\lambda \cdot \sqrt{\frac{\hbar c^5}{G_D}} \tag{2}$$

As $\left(\frac{D-2}{2}\right)^{\lambda}$ is dimensionless, the energy units remain correct. Similar consistency holds for Planck length, time, and mass.

Overall, TDSF preserves the validity of dimensional analysis across all generalized laws. It ensures that no artificial units are introduced, and that all physical quantities remain measurable and consistent across different spacetime dimensionalities.

8 Zero-Point Physics and Cosmological Implications

The Thompson Dimensional Scaling Framework has profound implications for vacuum energy, the cosmological constant, and Casimir effects. These phenomena, deeply rooted in quantum field theory, are sensitive to both geometry and dimensionality. TDSF offers a mathematically consistent way to scale these quantities across different spacetime dimensionalities.

8.1 Zero-Point Energy (ZPE)

The scaled expression for zero-point energy in D dimensions is:

$$E_{\text{ZPE}} = \frac{1}{4} \cdot \frac{c^5}{G_D} \cdot \left(\frac{D-2}{2}\right)^{\lambda+2\psi}$$

where ψ is an auxiliary scaling exponent associated with vacuum fluctuation density or curvature effects. This model implies that vacuum energy is dimension-sensitive, with observable consequences in high-energy and early-universe regimes.

8.2 Cosmological Constant

Using the above zero-point scaling, the effective cosmological constant becomes:

$$\Lambda_D = \frac{1}{32\pi} \cdot \frac{c^9}{G_D^2} \cdot \left(\frac{D-2}{2}\right)^{\lambda+2\psi}$$

This presents a novel mechanism for dimensional tuning of dark energy and may contribute to resolving the cosmological constant problem by predicting how Λ varies with hidden dimensions.

8.3 Casimir Effect

For parallel plates separated by a distance a, the Casimir force scales as:

$$F_{\text{Casimir},D} = \frac{1}{4} \cdot \frac{c^5}{G_D} \cdot \left(\frac{D-2}{2}\right)^{\lambda+2\psi} \cdot \frac{D-1}{a^D}$$

This predicts measurable corrections to Casimir forces at nanoscales if extra dimensions influence quantum vacuum behavior. It also provides an experimental pathway to constrain the dimensional scaling factors λ and ψ.

Together, these extensions suggest that zero-point physics, cosmology, and high-precision experiments can serve as sensitive probes of higher-dimensional structures described by TDSF.

9 Toward Falsifiability and Experimental Pathways

One of the most significant promises of the Thompson Dimensional Scaling Framework is its capacity to transform higher-dimensional physics from a purely speculative domain into a testable scientific framework. Unlike many string-theoretic or higher-dimensional proposals, TDSF provides concrete mathematical formulations that lead to specific, falsifiable predictions.

9.1 Constraints from Casimir Force Experiments

The dimensional dependence of the Casimir force offers a clear experimental target. Deviations from standard 4D predictions at nanoscales, particularly if distance-sensitive anomalies are observed, could be interpreted as evidence for extra-dimensional effects governed by the TDSF scaling factors λ and ψ.

9.2 Torsion-Balance and Fifth-Force Searches

Experiments such as those conducted by the Eöt-Wash group to detect deviations from Newtonian gravity at sub-millimeter scales may also place empirical bounds on D and λ. The TDSF-modified gravitational and electromagnetic laws offer an avenue for correlating such deviations with specific dimensional structures.

9.3 Implications for Cosmological Observables

The dimensionally scaled cosmological constant may also lead to testable consequences in the cosmic expansion rate, structure formation, or anisotropies in the cosmic microwave background. If higher-dimensional corrections are real, they may manifest as unexplained features in large-scale observations.

9.4 Parameter Fitting and Model Selection

As datasets improve, particularly in precision cosmology and quantum metrology, the parameters λ and ψ may be constrained through data-fitting techniques. This opens the door to statistical model comparison, allowing TDSF to compete with alternative theories on predictive power.

By grounding higher-dimensional physics in measurable phenomena, TDSF offers a path forward—one where speculation is tempered by falsifiability, and where theoretical elegance meets empirical rigor.

10 Testable Predictions and Experimental Relevance

The Thompson Dimensional Scaling Framework enables a range of falsifiable predictions that distinguish it from speculative higher-dimensional theories. These predictions include:

- **Casimir Force Deviations:** At nanoscale separations, the dimensional scaling predicts measurable deviations from the standard $\propto 1/a^4$ dependence, offering a testable signal using high-precision microelectromechanical systems (MEMS).
- **Short-Range Gravity Experiments:** TDSF implies modifications to Newtonian gravity at sub-millimeter scales. Torsion-balance experiments may detect a deviation correlated with the $\left(\frac{D-2}{2}\right)^{\lambda}$ term.
- **Zero-Point Energy Scaling:** The modified ZPE expression may offer insight into the cosmological constant problem and could manifest through precision spectroscopy or vacuum fluctuation studies.
- **Cosmological Signatures:** If the cosmological constant Λ_D varies with dimensionality as predicted, this could produce residual signatures in the CMB anisotropy spectrum or in large-scale structure surveys.

These pathways link the Thompson framework to real-world experimental tests, distinguishing it from models that remain entirely theoretical.

11 Conclusion and Future Work

The Thompson Dimensional Scaling Framework (TDSF) proposes a simple yet powerful generalization to known physical laws by introducing a scaling factor dependent on the number of spacetime dimensions. This factor systematically modifies mass, energy, momentum, field equations, and quantum relations, providing a unified structure that accommodates both standard 4D physics and higher-dimensional extensions.

The framework not only maintains consistency with known theories in four dimensions but opens new pathways for connecting extra dimensions to measurable quantities. It aligns with string theory's higher-dimensional structure, yet offers a concrete method to introduce falsifiability and predict experimental anomalies.

Future work should focus on refining the values of the scaling exponents λ and ψ through both theoretical derivation and experimental constraint. In parallel, the TDSF formalism could be extended to additional areas of physics, including thermodynamics, statistical mechanics, and quantum gravity.

Ultimately, TDSF represents a bridge between abstract dimensional mathematics and empirical science—a toolset for navigating the vast terrain of higher-dimensional theories with rigor and clarity.

Appendix A: Supplemental Thompson-Scaled Equations

This appendix contains additional equations referenced in prior visual disclosures of the Thompson Dimensional Scaling Framework (TDSF), but not included in the main body of this paper. All equations follow the generalized dimensional scaling factor:

$$\left(\frac{D-2}{2}\right)^{\lambda} \tag{3}$$

where D is the total number of spacetime dimensions and λ is the scaling exponent specific to each physical law or operator. An additional exponent ψ may appear in expressions related to zero-point fluctuations or vacuum effects.

A.1 Thompson Dimensional Mass-Energy Relation (TDMER)

A dimensionally scaled form of the famous $E = mc^2$ relation:

$$E_D = \left(\frac{D-2}{2}\right)^{\lambda} mc^2 \tag{4}$$

This models how rest energy varies in higher-dimensional spacetimes.

A.2 Thompson Dimensional Mass Operator (TDMO)

In quantum mechanical contexts, a mass operator may be generalized as:

$$\hat{M}_D = \left(\frac{D-2}{2}\right)^{\lambda} m_0 \tag{5}$$

where m_0 is the rest mass eigenvalue in 4D.

A.3 Dimensional Gravitational Redshift

A heuristic form of gravitational redshift with dimensional scaling:

$$\frac{\Delta f}{f} = \left(\frac{D-2}{2}\right)^{\lambda} \cdot \frac{GM}{rc^2} \tag{6}$$

This predicts redshift amplification in higher-dimensional gravitational wells.

A.4 Vacuum Path Integral (String Theory)

The Thompson-scaled vacuum functional from the Polyakov string action:

$$Z_D = \int \mathcal{D}X\, e^{iS_D}, \quad \text{where} \quad S_D = -\frac{T_0}{2}\left(\frac{D-2}{2}\right)^{\lambda} \int d^2\sigma \sqrt{-h} h^{ab} \partial_a X^\mu \partial_b X^\nu g^{(D)}_{\mu\nu} \tag{7}$$

This embeds dimensional dependence directly into the vacuum structure.

A.5 Dimensional Casimir Energy (Reformulated)

The energy per unit area between parallel plates:

$$E_{Casimir,D} = \frac{1}{4} \cdot \frac{c^5}{G_D} \cdot \left(\frac{D-2}{2}\right)^{\lambda+2\psi} \cdot \frac{D-1}{(D-2)a^{D-1}} \tag{8}$$

This refines the Casimir force formula by extracting an explicit energy density term.

These supplemental equations further illustrate the extensibility of the Thompson Dimensional Scaling Framework across theoretical domains not yet fully developed in the main body. Future work will expand upon these operators and functional integrals in their respective contexts.

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